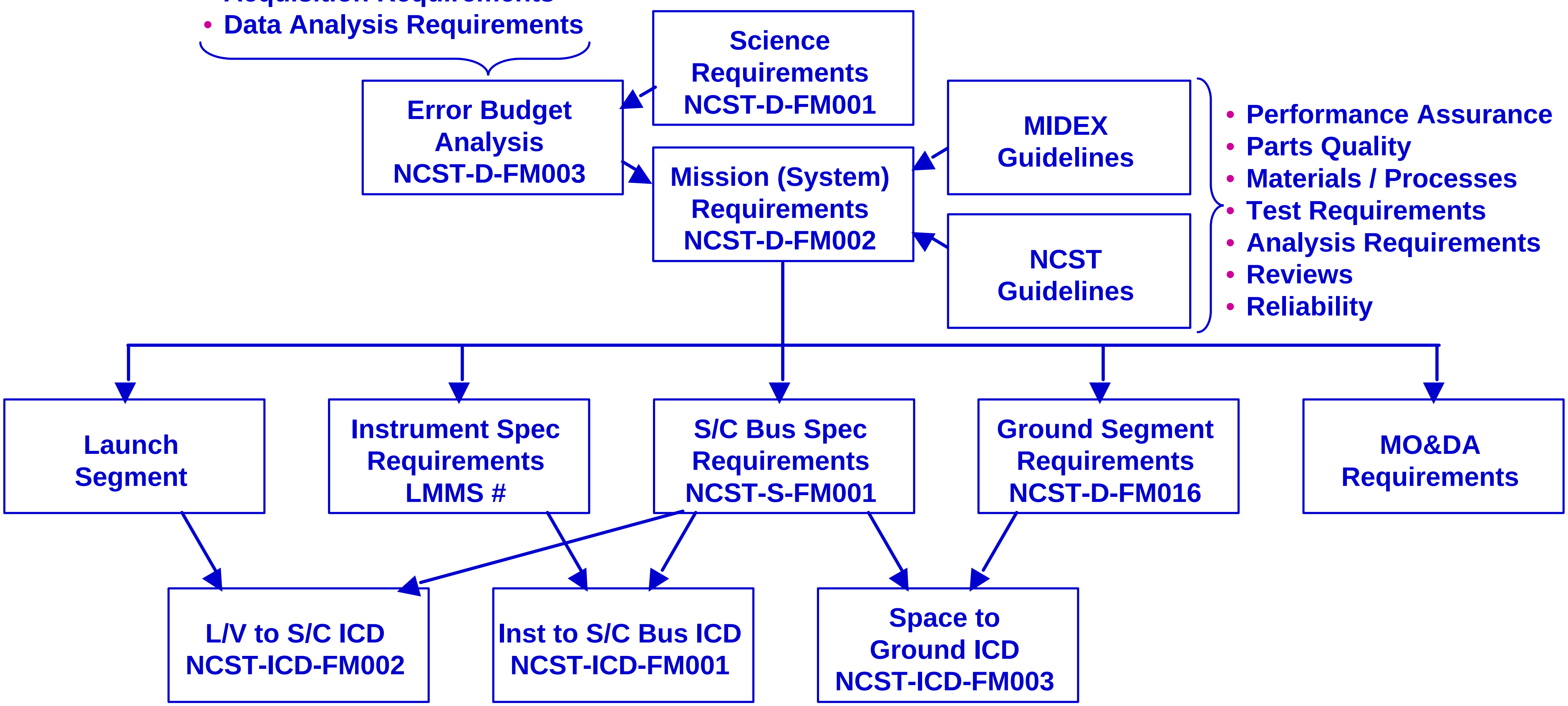
Mission Overview

Mark Johnson
Program Manager
NRL
202-404-5328
johnson@ssdd.nrl.navy.mil

Systems Engineering Requirements Flowdown

- Observation Requirements
- System Requirements
- Astrometric Requirements
  - Along Scan
  - Cross Scan
- Photometric Requirements
- Acquisition Requirements
- Data Analysis Requirements



Performance Metrics (At SRR) (1 of 5)

- Mass
  - Margins
    - Uncertainty in Estimates (Held at Subsystem Level)
    - 25% Added to Propellants, 20% on New Designs, 10% on Design Mods, 5% on Off-the-Shelf Hardware
  - Reserve
    - LV Throw Weight Less Mass est. With Uncertainty (Held at System Level)
    - 10% of Observatory Mass (Less Apogee Kick Motor) Desired
- Power
  - Instrument Carries 50% Design Margin (30% on Heater Power)
  - S/C Bus Carries 25% Design Margin
- Computer Resources
  - Computer Processing Power – 100% Margin on Computer Processing
  - Computer Memory – 100% Margin on CPU Memory
- RF Link Budget
  - 4 dB Margin on All Links Required

Performance Metrics - Mass (2 of 5)

12/4/00

Subsystem/Component	Mass Estimate	Margin	Mass W/Margin	Margin
	(Kg)	(Kg)	(Kg)	(%)
Flight Vehicle	976.5	104.8	1089.4	10.7%
Instrument Assembly	200.5	40.1	240.6	20.0%
Apogee Kick Motor	466.7	23.3	490	5.0%
Launch Vehicle Attach HW	7.37	0.74	8.11	10.0%
S/C Bus	309.3	41.4	350.7	13.4%
S/C Bus Structure	81.1	9.7	90.8	12.0%
S/C Bus RCS	57.8	12.1	69.9	20.9%
S/C Bus ADCS	14.4	1.68	16.1	11.7%
S/C Bus Mechanisms	45.8	5.3	51.1	11.6%
S/C Bus EPS	48.2	5.0	53.2	10.3%
S/C Bus RF	16.1	1.2	17.3	7.5%
S/C Bus CT&DH	12.7	2.0	14.7	15.4%
S/C Bus TCS	11.8	2.4	14.2	20.0%
Interstage Adapter	21.3	2.15	23.5	10.1%

Launch Vehicle Capability (2425-10)	1100	(Kg)
Mass Estimate (With Margin)	1089.4	(Kg)
Total Additional Reserves	10.6	(Kg)

Performance Metrics - Power (3 of 5)

Subsystem/Unit	Quantity	Mission Phase			
		Launch	Initial Acquisition/GTO	GEO/Operations	Safe-Hold Mode
Command, Telemetry and Data Handling	1	24.1	36.5	36.5	24.1
Attitude Determination and Control					
IMU (Litton LN200)	2	0	20	20	20
Sun Sensor & Electronics (Adcole)	1	1	1	1	1
Star Tracker (Ball CT-633)	2	0	20	20	0
Radio Frequency Subsystem					
Receiver	2	7.6	7.6	7.6	7.6
Transmitter	2	0	24	24	24
Power Amplifier	2	0	0	58	0
Mechanisms					
Solar Array Trim Tabs	6	0	0	0	0
CG Trim Mass	6	0	0	0	0
Electrical Power Subsystem					
Power Control Distribution Electronics	1	15	15	15	15
Battery	1	0	0	0	0
Spacecraft Thermal Control Subsystem					
In Sun		0	98	0	60
In Eclipse		0	154	64	154
Spacecraft Power By Operational Phase		47.7	376.1	246.1	305.7
25% Spacecraft Margin		11.9	94	61.5	76.4
Total Spacecraft Power By Operational Phase		59.6	470.1	307.6	382.1
Instrument					
Electronics		0	0	99	0
Operational Heater		0	0	133	0
Survival Heater		0	20	0	60
Instrument Power By Operational Phase		0	20	232	60
50% Instrument Margin		0.0	10.0	89.0	30.0
Total Instrument Power By Operational Phase		0.0	30.0	321.0	90.0
Total Observatory Power W/Margin		59.6	500.1	628	472.1

Performance Metrics - Computer Resources (4 of 5)

Function	Ops	Rate (Hz)	MIPS
Timer	4000	100	0.4
BC Manager	25000	20	0.5
GNC Exec	1000000	1	1.0
ADAC	750000	4	3.0
TM Formatter	20000	50	1.0
Payload TM Support	20000	20	0.4
HW Manager	40000	1	0.0
Downlink Manager	40000	10	0.4
SCL Data I/O	24000	25	0.6
SCL RTE	32000	25	0.8
Total			8.1
Available			20.0
Margin			**147%**

CPU Processing Requirements

Software Component	Code	Data (kB)	Total
Resource Manager			
• RTOS	256	256	512
• Drivers and ISRs	16	64	80
• Resource Management	64	96	160
Command and Telemetry			
• Bus Controller	6	4	10
• TLM Formatter	12	32	44
• SCL RTE/Data I/O	112	24	136
• Downlink Manager	4	1	5
Guidance, Navigation, and Control			
• GNC Total	87	32	119
Data Structures			
• Log Buffers	0	1088	1088
• Command History	0	32	32
• Onboard Database (Scripts & TLM)	0	640	640
• GNC Tables	0	1152	1152
FSW Total K Bytes Required			3978
Total Available			128000
Margin			3100%

CPU RAM Requirements (kB)

Performance Metrics - RF Margins (5 of 5)

Uplink Budget

Transmitter Power (200 W)	53.0 dBm
Line & Diplexer Loss	-2.0 dB
Antenna Gain (10 m)	44.0 dBi
Free Space Loss (Geosynch at 5 deg elev)	-190.3 dB
Atmosphere Loss (5 deg)	-0.5 dB
Minimum Antenna Gain	-17.0 dBi (Includes Hybrid Loss)
-Receiver Sensitivity	-(-118.0 dBm)
Margin	5.2 dB

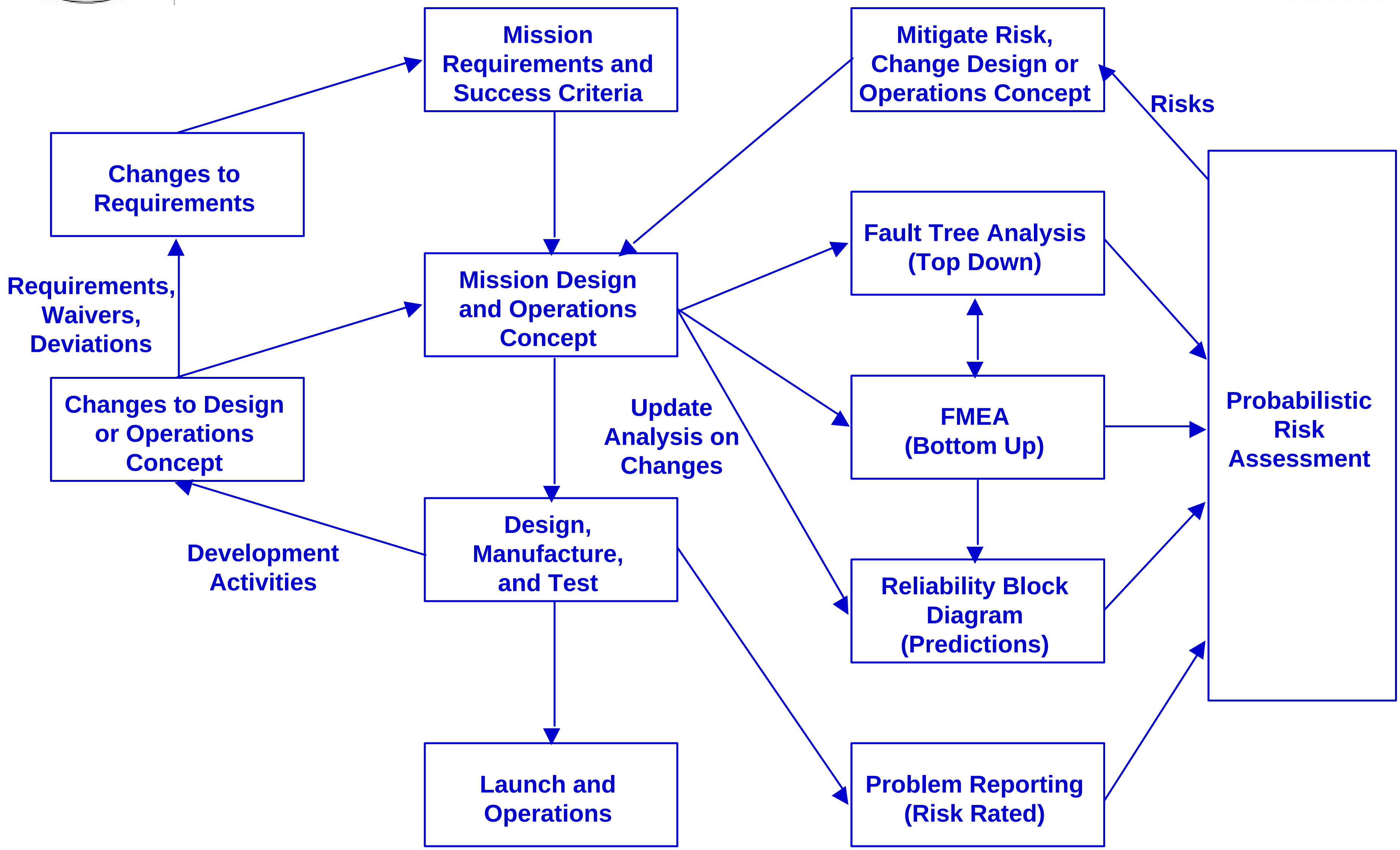
Downlink Budget (409 kbps, Geo)

Transmitter Power (w SSPA)	43.0 dBm (20W)
Diplexer and Switch Loss	-1.5 dB
Line Loss	-2.0 dB
Antenna Gain	-3.0 dBi
Free Space Loss (5 deg elev)	-191.8 dB
Atmosphere Loss (5 deg elev)	-0.5 dB
Data Rate	-56.1 dB Hz
Receive G/T	22.3 dB/K
Boltzmann's Constant	198.6 dBm/Hz/K
Eb/No	9.0 dB
Implementation Loss	-2.0 dB
Required Eb/No (10^{-6} BER)	-3.0 dB
Margin	4.0 dB

Downlink Budget (1 kbps, Geo)

Transmitter Power	36.0 dBm (4W)
Modulation Loss	-2.3 dBm
Diplexer & Switch Loss	-1.5 dB
Line Loss	-2.0 dB
Antenna Gain	-17.0 dBi (Includes Hybrid Loss)
Free Space Loss (5 deg elev)	-191.8 dB
Atmosphere Loss (5 deg elev)	-0.5 dB
Data Rate	-30.0 dB Hz
Receive G/T	22.3 dB/K
Boltzmann's Constant	198.6 dBm/Hz/K
Eb/No	11.8 dB
Implementation Loss	-2.0 dB
Required Eb/No (10^{-6} BER)	-3.0 dB
Margin	6.8 dB

Reliability Analysis Flow



System Trades

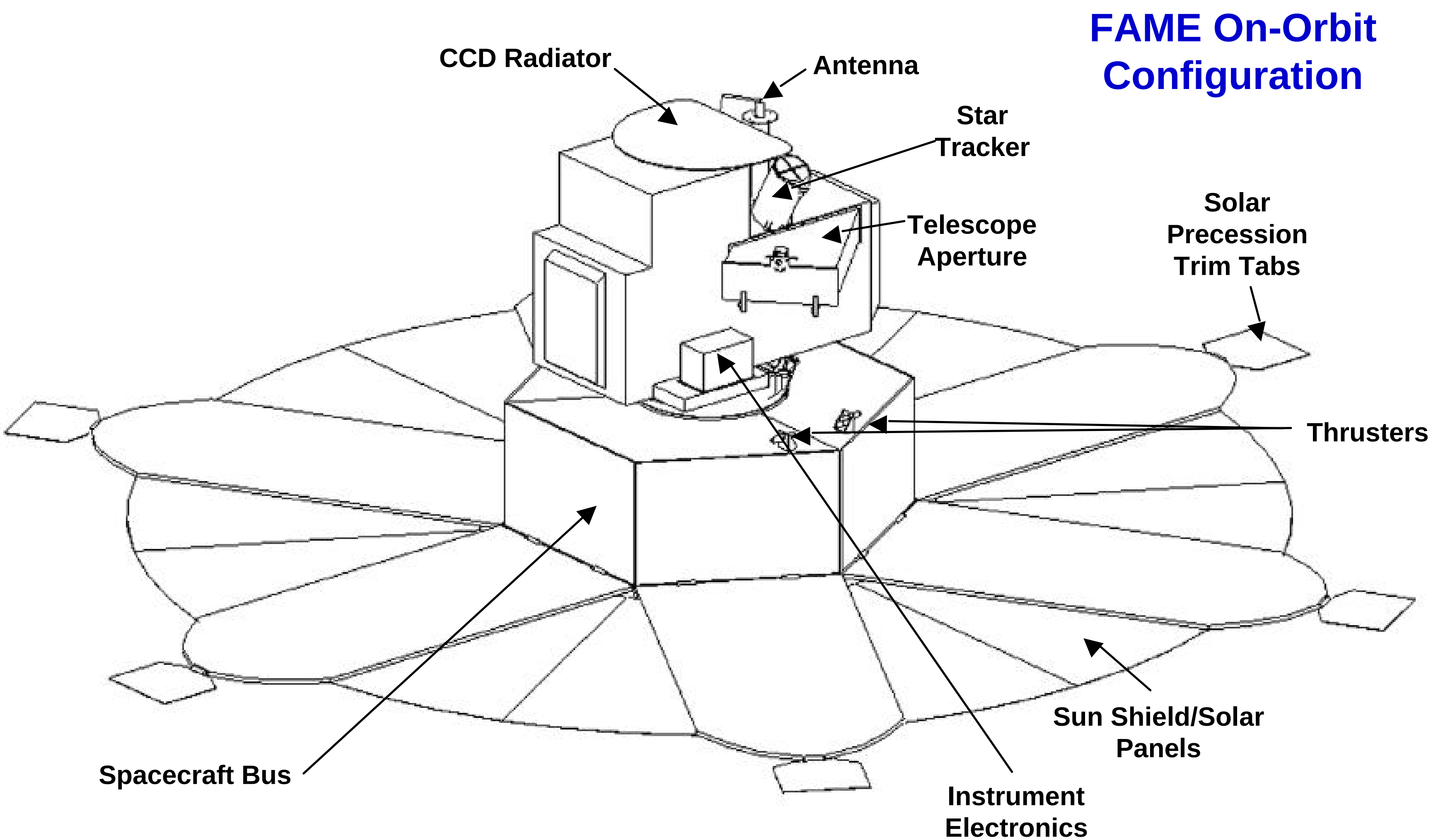
Trade	Options	Status	Result
Sun Angle	35°, 45°, 50°	Closed *	45±5°
Precession Backup (Passive vs Active)	None, Thrusters, Torque Rods	Open	
Measurement of Bright Stars	Filters, Start/Stop Tech.	Open	
Orbit	Geostationary vs GeoSync Drifting	Closed	105º W, Drifting Eccentric Orbit
Solar Array/Sun Shield	Single vs Multiple Hinges	Closed	Single Hinge
Data Rates (Function of Science Data)	RF Output/Ground ANT Characteristics	Open	
Ground Station Location	BP, DSN, Others	Closed	BP Primary Augmented by DSN
AKM Hole	Leave Open or Cover	Open	

* May Be Revisited When System Design Matures

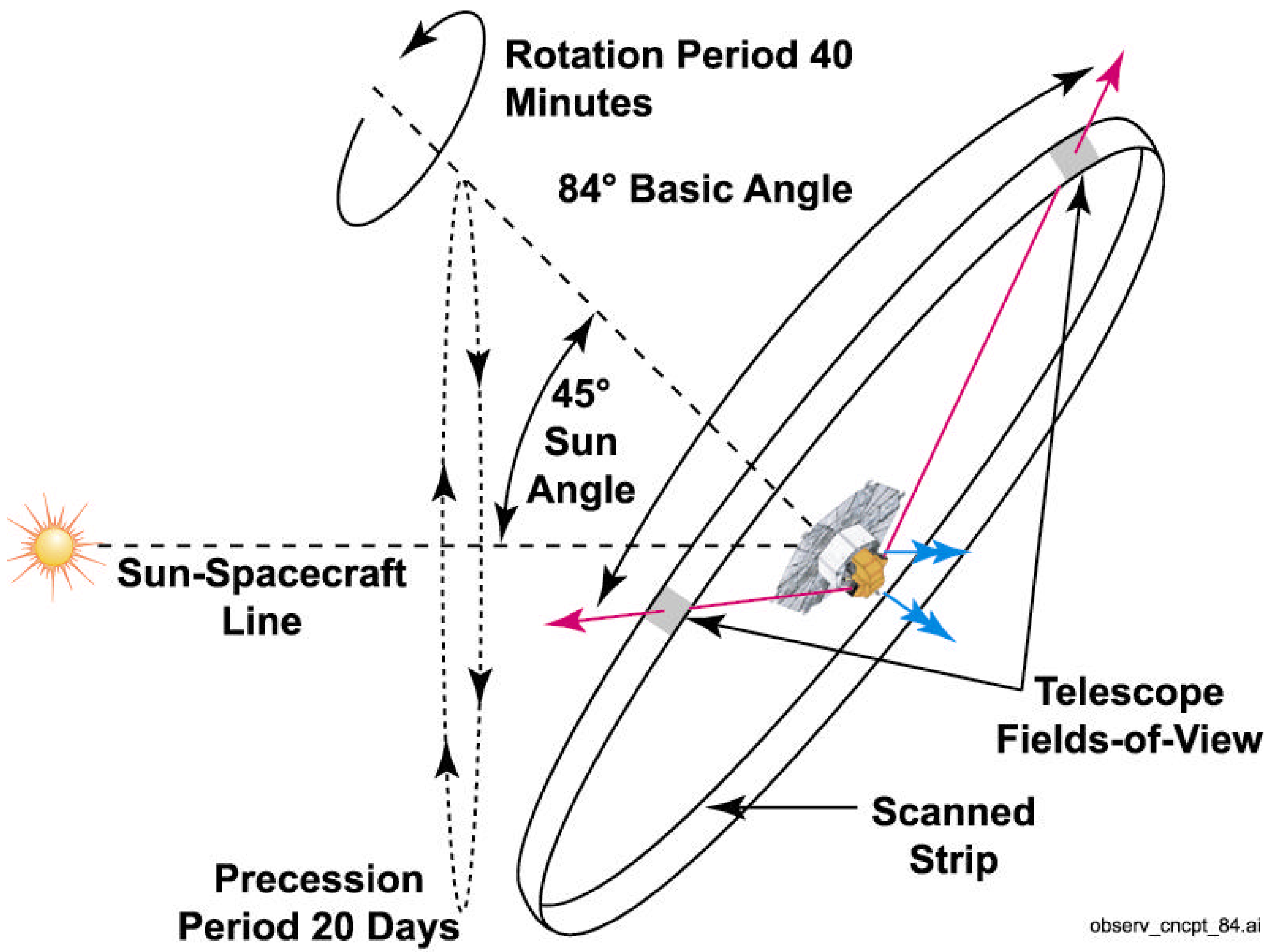
System Issues

Issue	Description	Possible Solutions
Mass Margins	• Current Mass Reserves Not Acceptable • Potential for Mass Growth	• Weight Savings • Descopes • Different Launch Vehicle
Inertia Properties	• Tight Requirements for Transverse Moments of Inertia • Tight Requirements for Product of Inertia	• Large Balance Masses • Additional Trim Masses
Optical Properties	• Not All Parameters of Surfaces Available • Degradation Properties Unknown (Uniformity)	• Establish Test Program • Size Trim Tabs to Accommodate Worst Case Conditions
Error Budget	• Ability to Meet All Requirements • Some Requirements Verified by Analysis Only	• May Need to Relax/Trade Error Budget Requirements
Optical Thermal Stability	• Time Constant/Stability of Optical System	• Analysis/Modeling of Error Sources

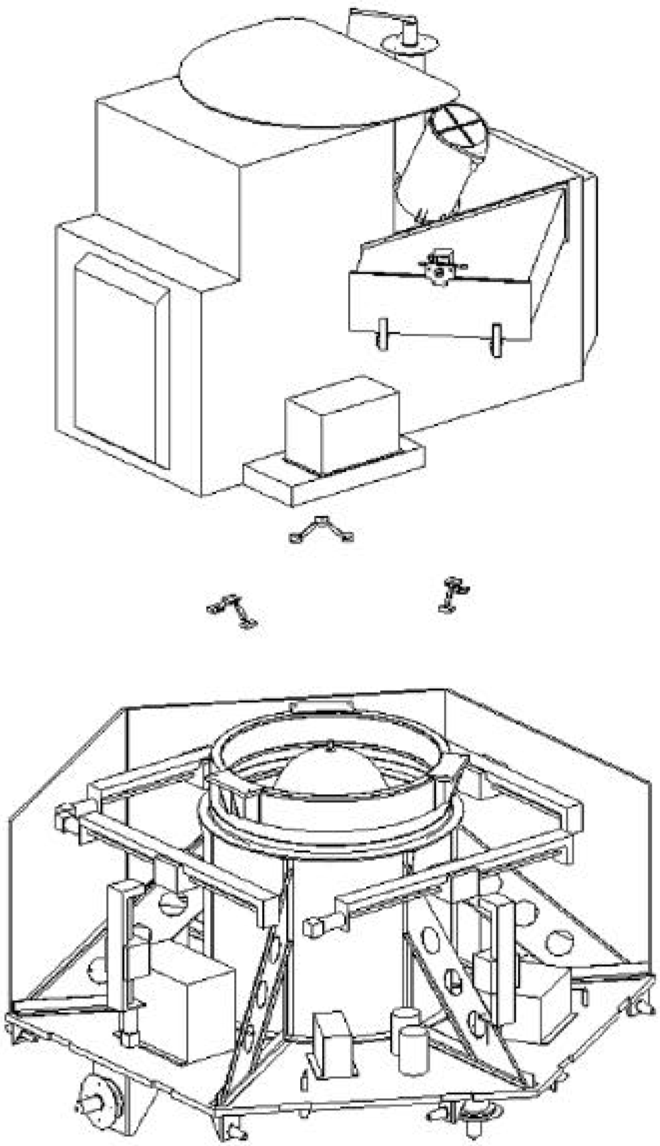
Operational Configuration



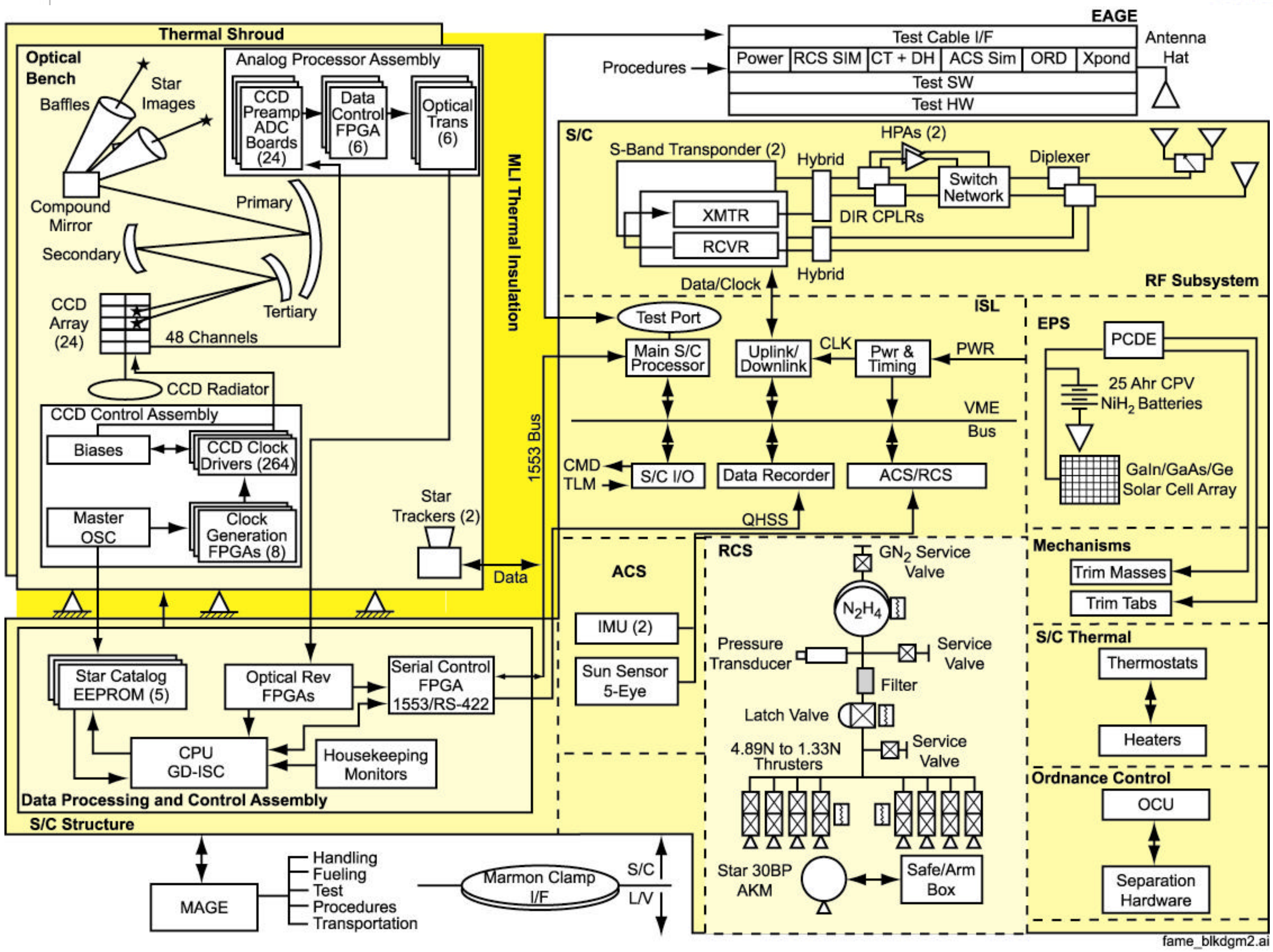
Observation Concept



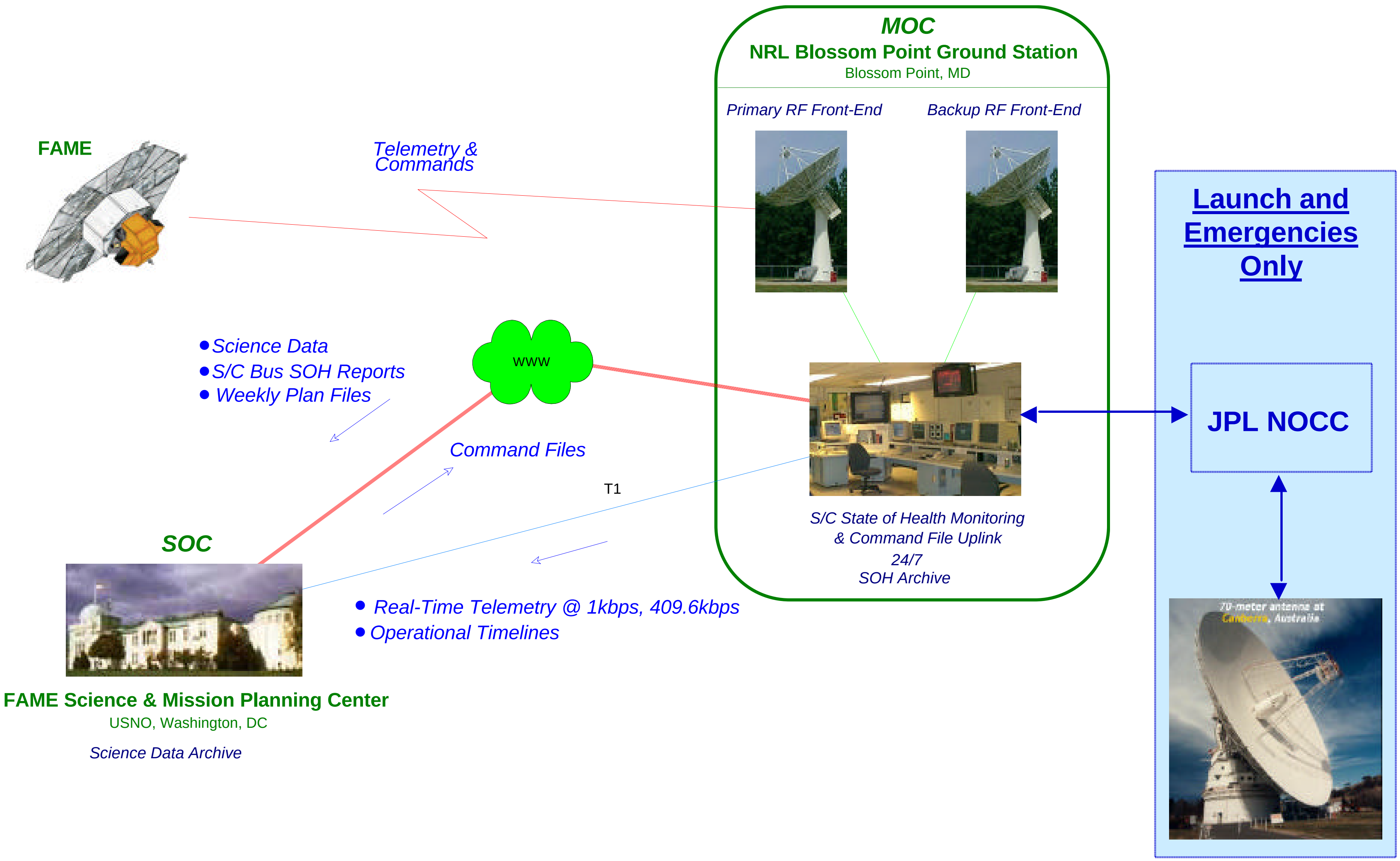
S/C Exploded View



S/C Bus Block Diagram



Operations Concept



Mission Design

- *Hipparcos* Style Observing Concept
  - One Passive Observation Mode
  - No Active Attitude Compensation
- Fixed Solar Arrays
  - Serve As Thermal Shield for Instrument
  - Harness Solar Pressure for Spin Axis Precession
  - Collect Energy for Batteries Used During Eclipses
- Redundancy in Selected Subsystems
  - Balance Cost Constraints While Maximizing Reliability/Mission Success
- Spacecraft Operates at GEO
  - Minimize Gravitational and Magnetic Torques
  - Provides Continuous Data Downlink
- Launch Vehicle Places Spacecraft in GTO
  - On-Board Solid Rocket Motor (SRM) Used to Circularize Orbit
  - SRM Jettisoned to Maintain Operational Spin Balance Requirements
- Blossom Point Used As Mission Operations Facility
  - Augmented With DSN Support During GTO Phase

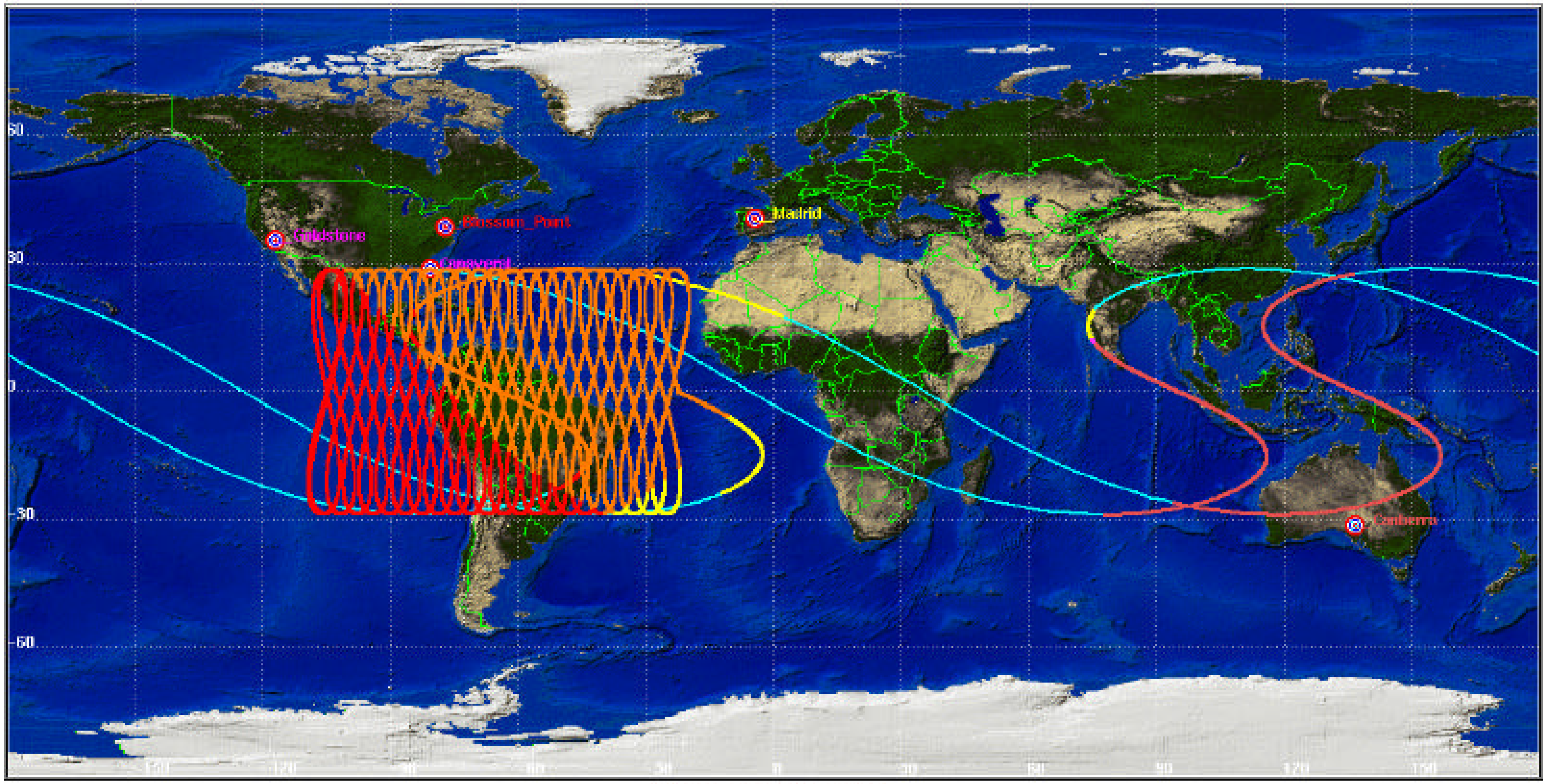
Mission Phases (1 of 3)

- Nominal Launch Window
  - Initial Launch Capability (ILC) Is Oct 30, 2004
  - Launch Time Constraints Driven by:
    - Desire to Minimize Eclipses During Mission Life
    - Launch Window Will Be Determined by Allowable Increase in Eclipse Duration (A 10% Increase in Eclipse Duration Allows for a Seven Hour Launch Window)
- Launch Phase
  - Begins With First Motion of Delta 2425, Ends With Separation From the Star-48 Upper Stage
  - S/C Controller, Receivers, Sun Sensors, and Power Control Electronics Powered for Launch
    - S/C Controller Is Pre-loaded With Event/Task List Activated Upon Separation From the Third Stage
  - Solar Arrays Stowed
  - Ordnance Subsystem Is “Safed” and Cannot Be Armed Until Separation From the Third Stage

FAME Coverage During Orbit Transfer

FAME Coverage During Orbit Transfer

Blossom Point + DSN Stations (5° min elev)



Blossom Point Coverage
Canberra Coverage
Madrid Coverage
Joint Blossom Point/Madrid Coverage
Joint Madrid/Canberra Coverage

WJB - 12/8/00

Mission Phases (2 of 3)

- GTO Phase (L + 25 Minutes to L + 1 1/2 Days)
  - Begins With Separation From the Third Stage
  - 10.6 Hour Orbit; Apogee at GEO Plus 300 km (Nominal)
  - S/C Aligns -Y Axis (TBR) With Sun Line; Arrays Remain Stowed
  - Ends With Firing of Apogee Kick Motor (AKM) on Rev 3
  - Blossom Point and DSN Sites Madrid and Canberra Used During This Phase
- SuperSync Phase (L + 12 Days to L + 28 days)
  - Circular at GEO Plus 300 km
  - Allow Drift at SuperSync Until S/C Drifts to 105 Deg West (28 Days)
    - Last Five Days Used to Trim SuperSync Orbit With Mission Orbit
  - AKM Jettisoned in SuperSync Orbit
  - Solar Arrays Deployed, Begin Checkout of S/C Attitude Modes, S/C Bus Health Checks
  - Single Delta-V Burn to Lower Perigee to GEO Minus 300 km Ends SuperSync Phase
  - Blossom Point Is Only Required Ground Station for Remainder of Mission

Mission Phases (3 of 3)

- Early GEO Operations (L + 28 Days to L + 40 Days)
  - Allow Time for S/C to Out-Gas Prior to Opening Instrument Covers [Launch + 30 days (TBR)]
  - Initial Adjustments of Trim Masses/Trim Tabs Using S/C Bus Attitude Sensors
  - P/L Electrical Checks Performed (Doors Closed)
  - Orbit Determination Checkout Begins
- EE&C Phase (L + 40ys to L + 50 [TBR] Days)
  - Open Instrument Covers
  - Instrument Optical Checkout/Calibration Begins
  - Additional Adjustments to Trim Masses/Trim Tabs Using Instrument Attitude Information
- Science Phase (L + 51 Days to L + 5 Years)
  - Science Operations
  - Baseline NASA Mission Through L + 2 1/2 Years
  - Extended Mission (Navy Funded) From L + 2 1/2 Years to L + 5 Years
- Disposal
  - At End of Mission; Single Burn to Raise Perigee to GEO Plus 300 km

FAME Orbit

- Drifting Geosynchronous Elliptical Orbit
  - Inclination Set by Launch Site at 28.7°
  - Orbital Period Matches Earth Rotation
    - Geopotential Resonance (With J22) Causes Oscillation About Stable Longitude at 105° West (Period ~ 2.5 Years)
  - Choose 105° West Longitude to Minimize Longitudinal Variation
  - Eccentricity Set at 0.0071 to Avoid Geostationary Belt
  - Inclination W.R.T Ecliptic >45° to Minimize Eclipses
    - Constrains Launch Window
  - No N-S Thrusting Planned
    - Provided Good Initial Orbit Insertion, No E-W Station-keeping Anticipated

Transfer to Orbit

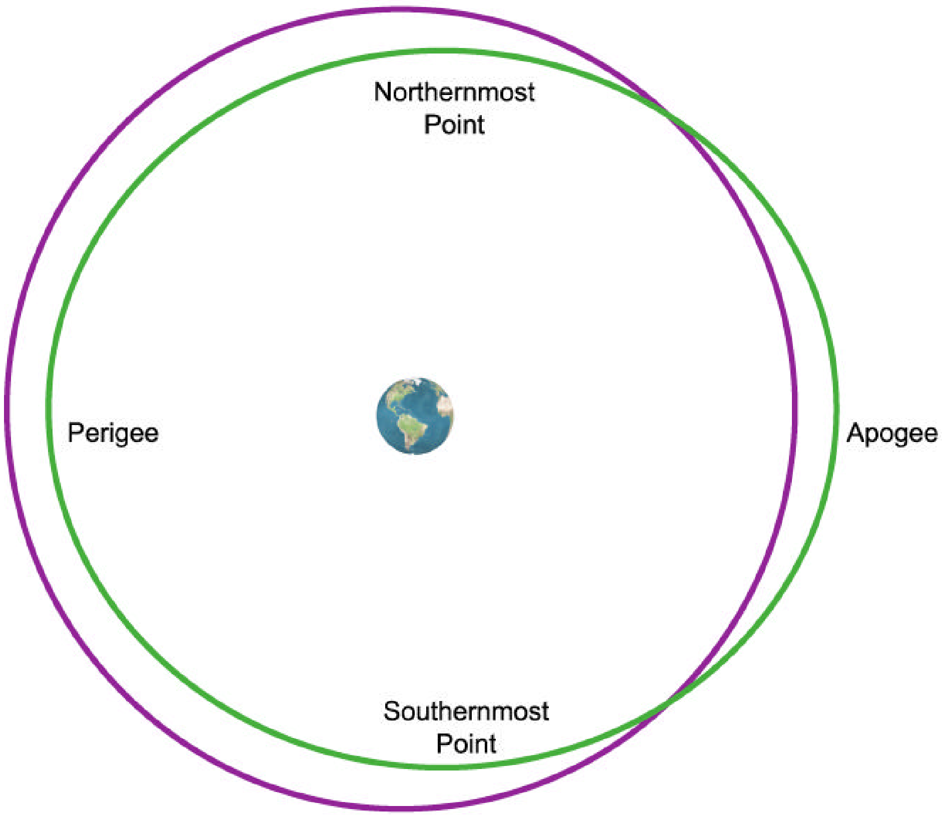
- **Nominal Orbit Transfer Plan**
  - **Baseline Launch Date 10/30/2004**
  - **Injection via Delta-II 2425 Into 185 x 36086 km GTO (1.5 Days)**
  - **AKM Firing to +300 km Supersynchronous Orbit (8 Days)**
  - **Two-Burn Maneuver Into GEO (Five Year Mission)**
    - **Depends on OD and Thrusting Accuracy From Supersynchronous Orbit**
    - **May Require Additional Trim Maneuvers**
  - **Disposal Orbit at GEO +300 km Altitude**

Drifting Elliptical Orbit

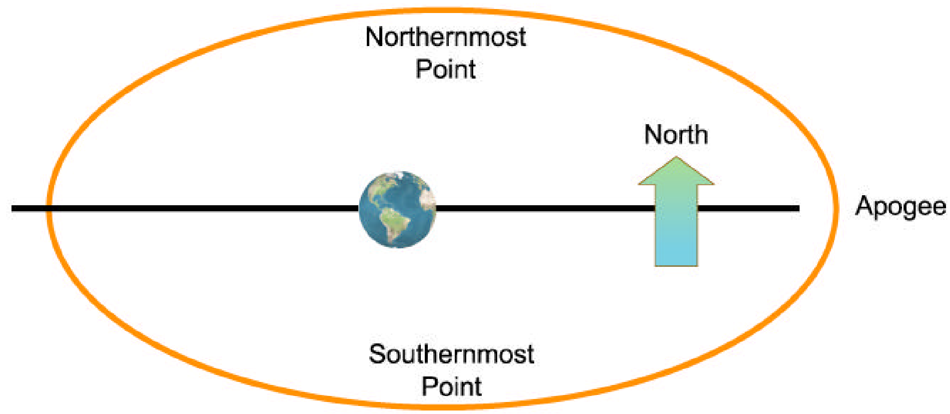
- Orbit Is Still "Geosynchronous," Not Geostationary or Circular
  - Instead of Circularizing at GEO Altitude, Leave Apogee +300 km
  - Bring Perigee 300 km Below GEO (Eccentricity = 0.007)
  - First-Order Orbit Rates Not Significantly Different
  - Over Five Years, Closest Approach to GEO Band Is >165 km
- Motivation
  - Eliminate or Minimize E-W Station-Keeping Propellant
  - Eliminate Need for or Reduce Frequency of E-W Station-Keeping
  - Reduce Fuel Sloshing Which Interferes With Science Goals

FAME Orbit Views (Not to Scale)

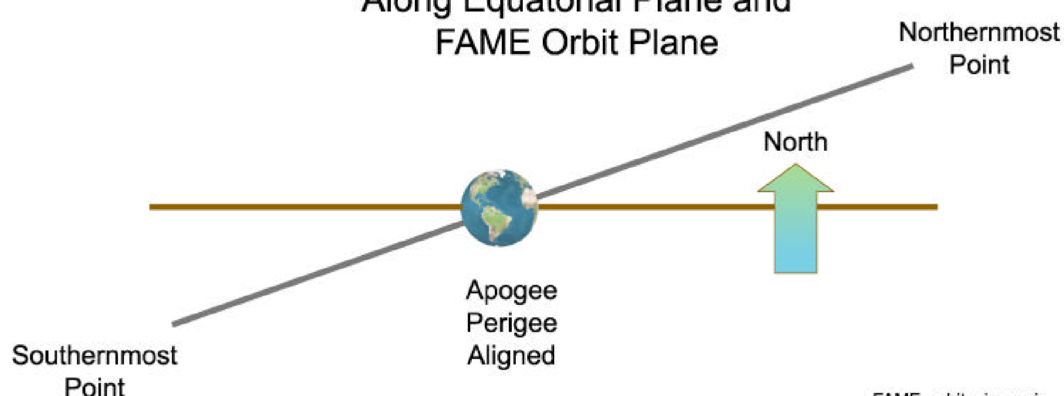
Down From North



Along Equatorial Plane



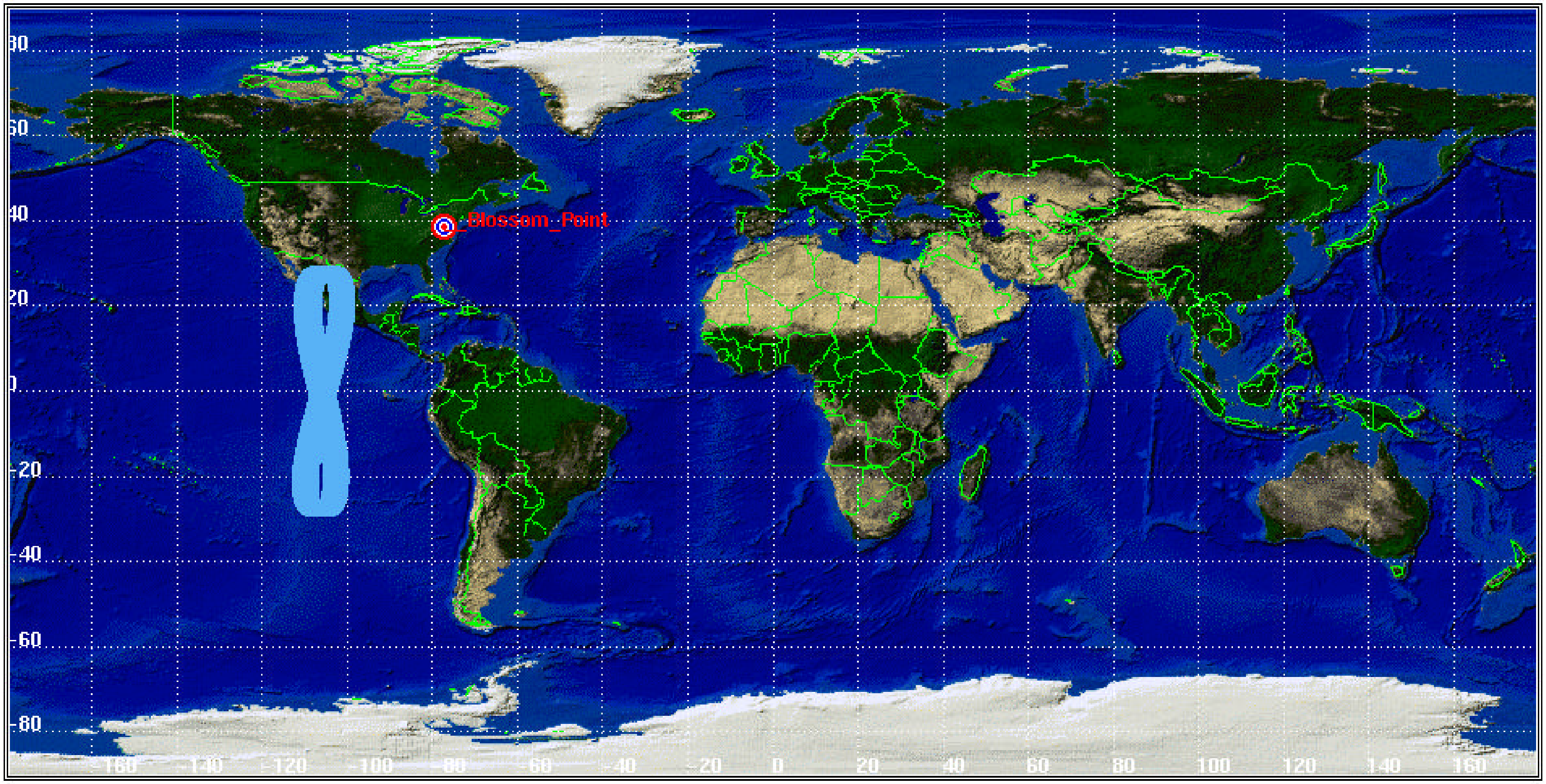
Along Equatorial Plane and
FAME Orbit Plane



FAME_orbit_views.ai

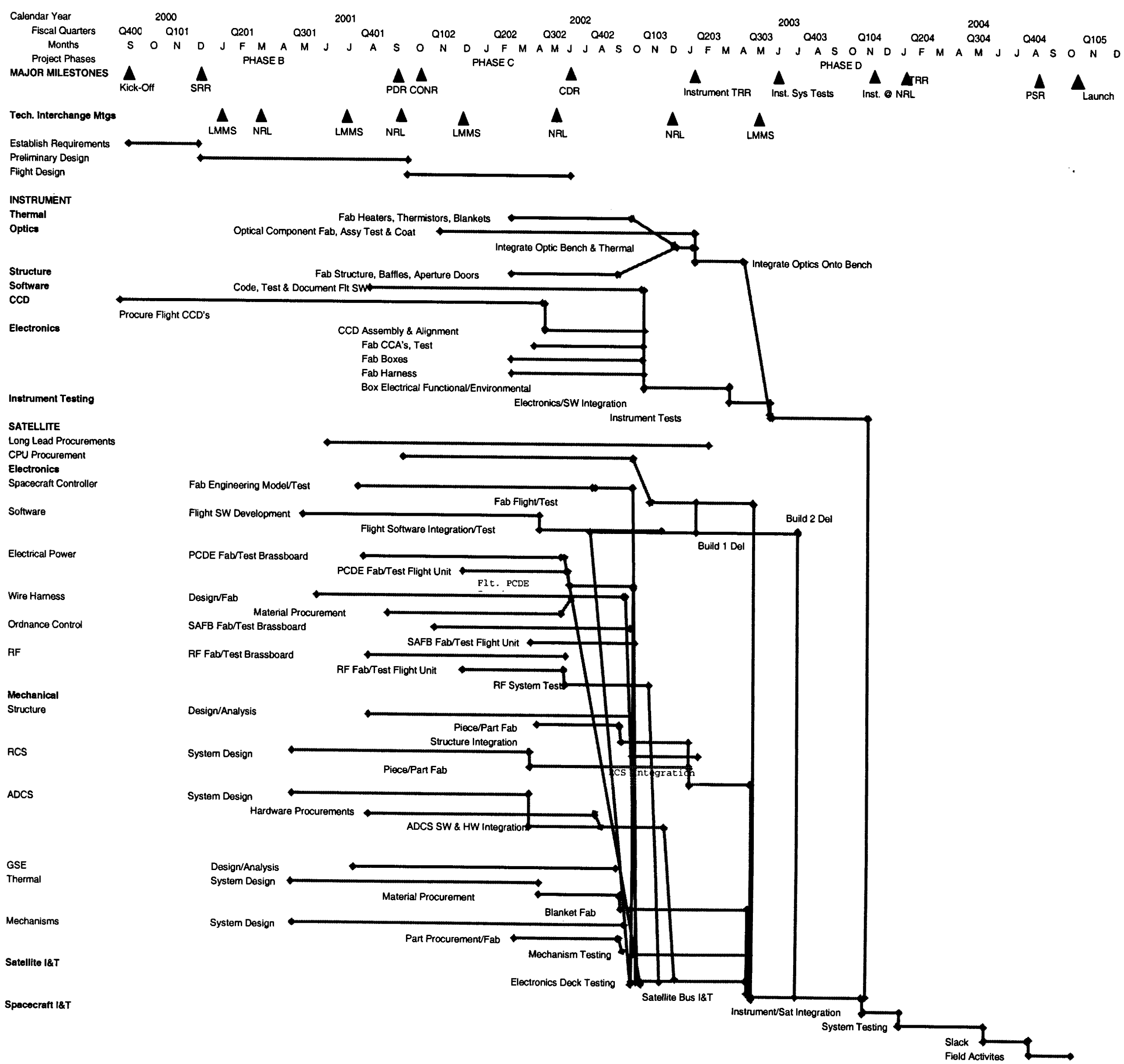
FAME Ground Track

FAME Ground Track with 105° W LAN at Insertion



Minimum Elevation over Blossom Point = 7.5° (at 109° W LAN)
LAN varies from 103° to 109° over 5 years with `850 day Period.

Schedule



Calendar Year
2000
2001
2002
2003
2004
Fiscal Quarters
Q400 Q101 Q201 Q301 Q401 Q102 Q202 Q302 Q402 Q103 Q203 Q303 Q403 Q104 Q204 Q304 Q404 Q105
Months
S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
Project Phases
PHASE B
PHASE C
PHASE D
MAJOR MILESTONES
Kick-Off
SRR
PDR CONR
CDR
Instrument TRR
Inst. Sys Tests
Inst. @ NRL
TRR
PSR
Launch
Tech. Interchange Mtgs
LMMS
NRL
LMMS
NRL
LMMS
NRL
NRL
LMMS
Establish Requirements
Preliminary Design
Flight Design
INSTRUMENT
Thermal
Optics
Fab Heaters, Thermistors, Blankets
Optical Component Fab, Assy Test & Coat
Integrate Optic Bench & Thermal
Integrate Optics Onto Bench
Structure
Software
CCD
Fab Structure, Baffles, Aperture Doors
Code, Test & Document Flt SW
Procure Flight CCD's
Electronics
CCD Assembly & Alignment
Fab CCA's, Test
Fab Boxes
Fab Harness
Box Electrical Functional/Environmental
Electronics/SW Integration
Instrument Testing
Instrument Tests
SATELLITE
Long Lead Procurements
CPU Procurement
Electronics
Spacecraft Controller
Fab Engineering Model/Test
Fab Flight/Test
Software
Flight SW Development
Flight Software Integration/Test
Build 2 Del
Build 1 Del
Electrical Power
PCDE Fab/Test Brassboard
PCDE Fab/Test Flight Unit
Flt. PCDE
Wire Harness
Design/Fab
Material Procurement
Ordnance Control
SAFB Fab/Test Brassboard
SAFB Fab/Test Flight Unit
RF
RF Fab/Test Brassboard
RF Fab/Test Flight Unit
RF System Test
Mechanical
Structure
Design/Analysis
Piece/Part Fab
Structure Integration
RCS
System Design
Piece/Part Fab
RCS Integration
ADCS
System Design
Hardware Procurements
ADCS SW & HW Integration
GSE
Thermal
Design/Analysis
System Design
Material Procurement
Blanket Fab
Mechanisms
System Design
Part Procurement/Fab
Mechanism Testing
Satellite I&T
Electronics Deck Testing
Satellite Bus I&T
Spacecraft I&T
Instrument/Sat Integration
System Testing
Slack
Field Activites